



## technology opportunity

# OTIS 4 Trajectory Optimization Program

*Simplified version improves accuracy and robustness*



The Optimal Trajectories by Implicit Simulation program version 4 (OTIS 4) simulates the trajectory performance of a wide variety of vehicles. Primarily a point mass, three-degree-of-freedom (3DOF) simulation program, OTIS 4 has options that allow six-degree-of-freedom (6DOF) simulations. The user inputs the vehicle models; there are no embedded, vehicle-specific aerodynamic or propulsion models. Flight paths can be generated with respect to any of the major bodies in the solar system. OTIS 4 allows progressively more detailed simulations as the vehicle and mission design advance.

## Benefits

- **Rapid.** More capability and faster execution while occupying less computer storage space than previous versions
- **Robust.** Tested more thoroughly than any similar software produced by NASA
- **Sophisticated.** Versatility to simulate a broad spectrum of vehicle trajectories
- **Accurate.** Negligible difference between true physical behavior and simulated behavior
- **User-friendly.** Easy to operate because user-provided input is simplified
- **Adaptable.** Runs on a DOS, Unix/Linux, or Macintosh system—or on any computer that has a Fortran 95 compiler
- **Economical.** Accomplishes tasks in less time and requires fewer analysts

## Applications

- **Aerospace industry:** development programs for personal air vehicles, subsonic aircraft, missiles, hypersonic systems, extraterrestrial exploration
- **Non-aerospace industry:** performance verification and validation activities, feasibility studies, advanced missile projects, submersible marine vehicles

## Technology Details

### *How It Works*

OTIS 4 is a general-purpose software program used for trajectory performance studies.

Users can simulate a wide variety of vehicles defined by user inputs. The program uses trajectory simulation and optimization to predict how a vehicle will perform and to determine how best to fly a given vehicle.

OTIS 4 provides two general modes of operation: explicit trajectory integration, and optimization using either explicit or implicit integration. A calculator that recognizes commonly used mathematical functions, operators, and precedence rules enables the user to compute new quantities needed to resolve a specific trajectory problem. An innovative method for constructing constraints between phases of a simulation greatly expands the range of problems that OTIS 4 can solve and eliminates a major source of user error by creating a mathematically correct implementation of transphase constraints.

The measure between true physical behavior and the simulation is called a “defect.” OTIS 4 contains a unique method of taking this measurement, called a “quadrature defect” that has proved to be very stable and offer excellent convergence properties. This method has reduced defect values to nearly zero, attaining a very credible and accurate solution to an optimal control problem.

### *Why It Is Better*

OTIS 4 provides the latest mathematical techniques for solving trajectory optimization problems and is easy to learn and master. Earlier versions of OTIS proved far less user-friendly and were grounded in only one form of implicit integration. Now, OTIS 4 provides the capability to perform a broad spectrum of applications in one unified package. It uses state-of-the-art solution methods for optimizing trajectories and vehicle design parameters.

Users input commands via metastrings, a set of keywords that concisely convey specific but common information or actions. Metastrings are highly intuitive to the trajectory and mission analyst and specify functions pertinent to the simulation.

OTIS 4 offers many discrete, direct solution methods in one unified package is one of the best-tested and competent versions of trajectory optimization software that NASA has produced. Its use throughout the aerospace community, in both preliminary design efforts and detailed analyses, demonstrates its superior ability as a reliable, accurate, and robust trajectory analysis tool.

OTIS 4 can easily be used for non-aerospace applications. The program is distributed with software that automates its execution. It can run on any computer that has a Fortran 95 compiler, including Windows, Unix/Linux, or Macintosh OS X.

OTIS 4 is available for download from the NASA GRC Software Repository after completion of a Software Usage Agreement.

For more information on the OTIS 4 software and on obtaining OTIS 4, go to: <http://otis.grc.nasa.gov/>

For best performance, OTIS 4 relies on the non-linear optimization program SNOPT. NASA does not distribute the source code to SNOPT with OTIS 4. Users must purchase their own copy of SNOPT from Stanford Business Software Inc. (<http://www.sbsi-sol-optimize.com>)

## For More Information

For more information about other technology licensing and partnering opportunities, please visit:

**Technology Transfer and Partnership Office**  
**NASA Glenn Research Center**  
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